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The effect of use of the audiovisual tactile on sensory recovery following hand replantation: A Case Report

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Abstract

Introduction: The aim of this study is to test if deprivation of tactile sense can be compensated by the hearing sense, early after hand replantation. Method: "Audiovisual tactile" apparatus was used early after hand replantation. In a 28-year-old man. Evaluation was done at regular intervals in 6, 9 and 18 months after the introduction of the intervention. Results: Results showed that sensory improvement is better than in the patient who used the artificial sensibility regimen compared with the one who did not.

Keywords: Replantation; Audiovisual tactile apparatus; Hand sensibility; Neuroscience

1. Introduction

Hand replantation requires immediate and careful rehabilitation.Changes in cortical maps in humans after chronic limb amputation has been studied by the use of neuromagnetic and neuroelectric source imaging, fMRI and PET. In all, these studies indicate that areas of primary somatosensory cortex that lose the hand become functionally reactivated by uninjured inputs from the face and/or arm stump (Wall, Xu, & Wang, 2002; Ramachandran, Stewart, & Rogers-Ramachandran, 1992).

The cortical reorganization secondary to amputation of the hand can be reversed if the amputated body part is reattached. By the use of fMRI techniques, it has been demonstrated that transplantation of a homologous hand to an amputee is followed by a continuous expansion of the corresponding projectional hand area in motor cortex, occurring parallel to increase in use of the transplanted hand. The hand motor projection area has been found to be regained within 6 months (Giraux, Sirigu, Schneider, & Dubernard, 2001).

Our senses work together to provide protection, recognition and action. Intact senses are sharpened when one sense is weakened- a well-known phenomenon about the blind and deaf (Rosen, Balkenius, & Lundborg, 2004). The resemblance in perceptual experience between sound and touch is bridged by the vibratory sense that represents a close connection between pressure sense and auditory sense (Katz, 1989). Considering this, and the delicate capacity of the hearing sense to discriminate between the complex patterns of frequencies, it is reasonable to assume that hearing is able to take over functions normally devoted to touch.

Cortical audio-tactile interaction has been reported in animal and human studies. In addition, Rosen and Lundborg have presented a model for alternative sensibility, based on sense substitution, using hearing as a substitute for sensibility (Rosen et al., 2003; Hassan-Zadeh, Mahmoodaliloo, Bakhshipour, Roofigari, & Shariat-Zadeh, 2010).

Our hypothesis was to provide the somatosensory cortex with an alternate 'sensory input' when regenerating nerve fibers have not yet reached the targets. We used acoustic signal from piezoelectric sensors that were attached under different textures on the board (Fig 1). The Audiovisual Tactile makes it possible to touch different textures by denervated finger and hear different noises. This method allows early sensory re-learning, long before any reinnervation can be identified, in order to feed the sensory cortex

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with relevant information. It maintains the cortical map from the affected hand until 'real' sensibility is present (Rosen et al., 2003). In this study "audiovisual tactile" was used early (from the first post-operative day) after replantation of the dominant hand at wrist level in a 28-year-old man. Sensory evaluation (Semmes Weinstein monofilament test, static two point discrimination test and the shape texture identification) was done at regular intervals in 6 and 18 months after introduction of the intervention. Sensory domain score was calculated according to Rosen score (Rosen & Lundborg, 2000).

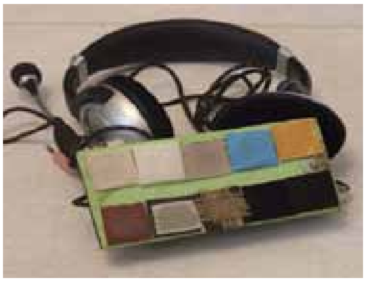

Fig 1.

2. Method

2.1. Case report

In this study the subject was equipped with an Audiovisual Tactile from the first post-operative day and underwent a sensory re-learning program at this time. There is multi and cross- modal activity of the brain based on multi sensory neurons that receive more than one type of sensory signals. It has been demonstrated that we are able to extract information from one sensory modality and use it in another by using poly-modal association areas. In the "Audiovisual tactile" Apparatus piezoelectric sensors are attached under the different textures. Patient can listen to what the hand feels. Thus, auditory stimuli – specific and typical friction sounds are associated with touching of various textures. Then traditional treatment with sensory re-education was started when some evidence of reinnervation was present in the hand. Two patients with replantation of the dominant hand at wrist level aged 28 years and 32 years participated in the study. In both cases were treated with a hand replantation within 24 hours from the injury by the same surgeon. Table 1 includes the demographic data of the two study subjects. One of the patients used the Audiovisual Tactile while carrying out conventional rehabilitation following hand replantation, including specific sensory re-education exercises there daily, from the first post-operative day through the first 3 post-operative months. At the 3 months follow-up, subject received information and a home program about conventional sensory re-education.

Table 1-Demographic data

	Audiovisual Tactile training	Conventional training
Age	28	32
Gender	male	male
Injury	Dominant hand Replantation	Dominant hand Replantation

2.2. Sensory re-education protocol

From the first post-operative day, intervention was introduced. During the immobilization period, wooden dowel was used and the patient himself performed passive stimulation and trained to identify two different textures and localize touch with one of the two textures on the denervated fingers. This program was done 3 times every for about 15 to 20 minutes 3 days a week. Classic training principles for sensory re-education (Dellon, 1997; Wynn Parry & Salter, 1976) was used, i.e. touch was performed, alternatively with and without looking, while concentrating in a quiet environment. The patient was instructed to concentrate on the textures that gave a specific sound. Once the patient was allowed to move the hand freely, the Audiovisual Tactile was introduced. At this point, training with Audiovisual Tactile also included a period of use the Audiovisual Tactile during light activities twice every day, each one lasting 20 minutes. Training with the Audiovisual Tactile finished and "conventional sensory re-education was introduced when perception of touch/pressure (SWM 4.56) could be detected in the affected area, which was usually 3 to 4 months postoperatively. There were follow-up 6, 9 and 12 months after introduction of the intervention (Rosen et al., 2003).

1.3. Assessment of Hand Function

Assessment was performed according to standardized procedures Perception of touch, measured with Semmes-Weinstein monofilaments (SWM). The summarized SWM measure points were the three 'critical sites' described by Bell-Krotoski (i.e. pulps of the thumb and the index finger and proximal phalanx of the index finger in median nerve injuries, and pulp of the little finger, proximal phalanx of the little finger and proximal hypothenar eminence in ulnar nerve injuries) (ASHT, 1992; Bell-Krotoski, 2002; Rosen & Lundborg, 1999).Classic static 2PD (Disk Criminator) (ASHT, 1992). Were used for assessment of tactile gnosis. 2PD testing was carried out according to the "Moberg Method" (Moberg, 1991), described by the ASSH and ASHT (ASHT, 1992). The test is carried out in descending order, starting with 15mm to assess the level at which responses were correct (7 out of 10 correct at just blanching of the skin), and quantification 0-3 (0 ≥ 16 mm, 1 = 11-15 mm, 2 = 6-10 mm, 3 ≤ 6 (ASHT, 1992). Shape and texture identification test (STI test) was performed according to Rosen et al. (Rosen, & Lundborg, 1999). Identification of three shapes and three simplified textures of increasing difficulty were performed with the index finger for median nerve repairs and fifth finger for ulnar nerve repairs. In patients with both median and ulnar nerve repair, digit II and digit V were examined. Maximum result and normal was 6 points.

Assessments of sensory function were performed at regular intervals in 6, 9, and 18 months after introduction of the intervention.

2. Results

There was an improvement in overall score especially in the sensory domain of the instrument for outcome after hand replantation over the 18 months after introduction of the intervention. Sensory function, measured with SWMs, Two-point discrimination and STI test improved significantly in the patient who used the artificial sensibility regimen compared with the one who did not (Table 2).

Table 2 –Sensory Domain Results

	9 Month		18 Month	
	Ulnar nerve territory	Median nerve territory	Ulnar nerve territory	Median nerve territory
Audiovisual tactile training	0.4	0.06	1.08	0.65
Conventional training	0.02	0	0.56	0.15

3. Discussion

Lack of a sensory input not only alters the cortical circuitry subserving the deprived sense, but also produces compensatory changes in the functionality of other sensory modalities. To interact successfully with the environment and to compensate for environmental challenges, the human brain must integrate information originating in different sensory modalities. Such integration occurs in non-primary associative regions of the human brain. Additionally, recent investigations have documented the involvement of the primary visual cortex in processing tactile information in blind humans to a larger extent than in sighted controls. This form of cross-modal plasticity highlights the capacity of the human central nervous system to reorganize after chronic visual deprivation.

In this method, as we showed in previous study (Hassan-Zade et al., 2010), an alternate afferent inflow from the hand early after hand replantation, mediated through the hearing sense, implying that deprivation of one sense can be compensated by another sense. This sensory "by-pass" was used with the intention of improving recovery of functional sensibility by maintaining an active sensory map of the hand in the somatosensory cortex during the deafferentation period.

In this study, our findings show that postoperative use of a device using hearing as a substitution for sensation in hand replantation may have considerable potential value for speeding up cortical integration of a replanted hand. The principle is based on the brain's capacity for multimodal plasticity, implying that deprivation of one sense (somatosensory) can be compensated for by another sense (auditory). We also followed Rosen and Lundborg's method in this study. In the present study "audiovisual tactile" was used early (from the first post-operative day) after hand replantation in a 28-year-old man. Sensory evaluation was done at regular intervals in 6, 9 and 18 months after introduction of the intervention. The Audiovisual Tactile makes it possible to touch different textures by denervated finger and hear different noises. (Direct touch by sensor glove system is not possible). The findings in this study supported results of Rosen and Lundborg's study.

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